International Journal of Engineering and Advanced Research Technology (IJEART)
ISSN: 2454-9290, Volume-2, Issue-10, October 2016

Capacitive dividers on the high voltage lines

Haroun Abba Labane, Alphonse Omboua

***Abstract*— In the developing countries, several villages are crossed by lines with high voltage yet the populations do not profit from the electricity which passes above their heads. The classical solution for the transformation of the very high voltage into low voltage for the profit of the rural populations is expensive and is not economically profitable for the distributors of electrical energy. The voltage dividers already used like transformers in the stations, can be resized for the extraction of small quantities along high voltage lines. This single-phase technique, would plaid in favor of the reasonable costs. On the work of transporting, the high voltage line would assume the role of distributor of electrical energy to the rural populations. This article is dedicated to the detailed research of the system, for the control of the parameters of the choice equipment, for an easy dimensioning in rural electrification.**

***Index Terms*— Extracting, Energy, capacitive dividers, high voltage lines.**

I. INTRODUCTION

PRESENTATION OF A CAPACITIVE VOLTAGE DIVIDER

For this kind of power supply, the return of the electric power being done by the ground. So, the level of the voltage of transport is reduced to a level of distribution then allowing the use of a MV/LV distribution transformer to pass from the average voltage level to that of the use. One distinguishes 3 parts associated on three voltage levels: high, medium and low.

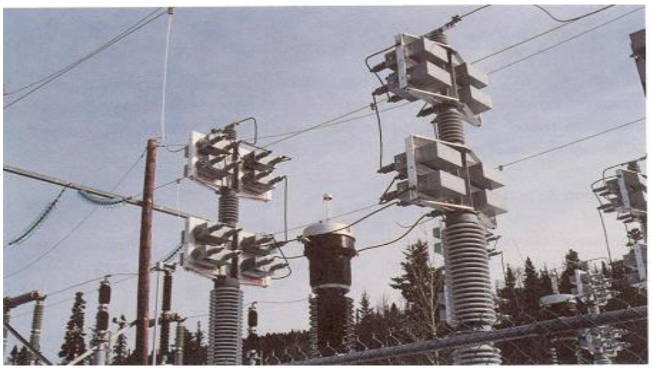

Fig. 1: Capacitive voltage divider - Photo Hydro Quebec 225 kV/20 kV

- The high voltage is composed by the line and the capacitor C_1 for coupling.
- The medium voltage is composed by the capacitor C_2, the compensation coil, the damping filter and the primary transformer MV/LV.
-The Low voltage includes the second transformer and the load impedance Z_n.

II. SCHEMA OF THE PRINCIPLE CAPACITIVE DIVIDER

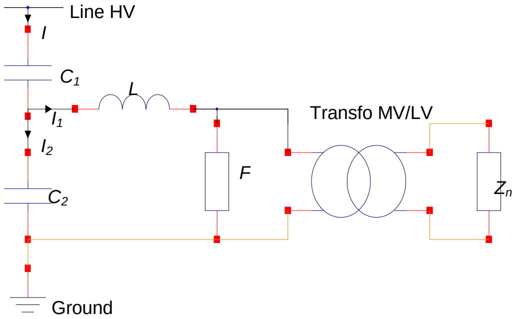

Fig.2: Schema of the capacitive divider

The equivalent schema reduced to the primary transformer is:

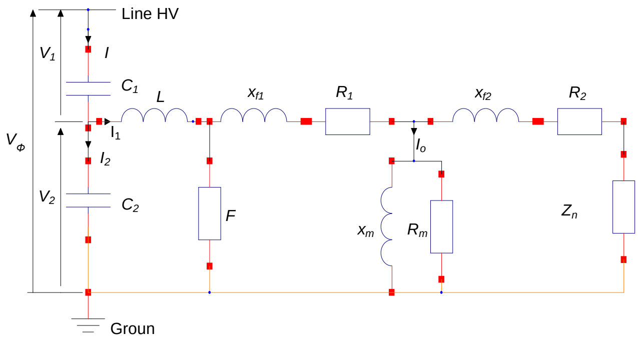

Fig.3: Schema of the system reduced to the primary MV/LV transformer

Notations

Z_1 ,Z_2: respectively impedances of capacity C_1 and C_2
Z_2: impedance of capacity C_2
Z_n: impedance of the load to be supplied
Z_{PO}: impedance of the compensation coil
Z_F: impedance of the shock absorber filter
Z: equivalent impedance of the network subjected to the medium voltage V_2
R_1: Resistance of winding of the primary transformer
R_2: Resistance of winding of the second transformer
R_m: Resistor losses by iron in the magnetic circuit of the transformer
R_p: Equivalent resistance of the transformer (reduce to the primary)
X_{F1}: Reactance of winding of the primary transformer
X_{F2}: Reactance of winding of the secondary transformer
X_m: Reactance of magnetizing the MV/LV transformer
V_1 ,V_2: respectively voltages of poles capacity C_1 and C_2
V_ϕ: Single Voltage of HV Line
U_n: Nominal voltage of the load Z_n
S_n: Apparent power of the load
$cos\varphi$: Factor of power of the load
$Z_w = Z\text{-}Z_{po}$
α: Real part of Z_w

β: Imaginary part of Z_w
F: Filter shock absorber
k: Transformation ratio
I: The primary current through C_1
I_1: The current in the branch MT
I_2: The current through the capacitor C_2
L: Inductance coil of compensation of agreement coil
T: MV/LV transformer

Role of the compensation coil:
The compensation coil plays a role in the compensation of the reactive energy that the capacitors produce.

Role of the filter shock absorber:
The filter shock absorber (F) is at the same time used to filter harmonics on the side distribution.

III. CALCULATION OF THE IMPEDANCE Z SUBJECTED TO THE MV VOLTAGE V_2

In load, the current value I_O is negligible that we can remove the branch of magnetizing and the voltage V_2 is applied to the following circuit:

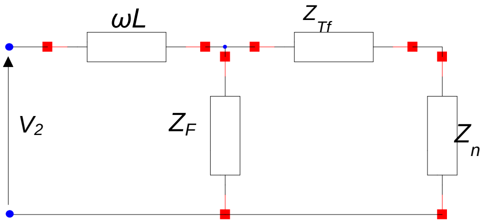

Fig. 4: Summary of the circuit under the MV voltage V_2

(a) is the ratio: voltage medium / low voltage transformer.
x_p and R_p be the reactance and resistance of the transformer reduced to the primary and $\bar{Z}_{p0} = jL\omega$

We have : $x_p = xf_1 + a^2 xf_2$; $R_p = R_1 + a^2 R_2$;

$$\bar{Z} = \bar{Z}_{p0} + \frac{(R_p + jx_p + a^2\bar{Z}_n)\times\bar{Z}_F}{(R_p + jx_p + a^2\bar{Z}_n)+\bar{Z}_F}$$

We set $\bar{Z}_W = \dfrac{(R_p + jx_p + a^2\bar{Z}_n)\times\bar{Z}_F}{(R_p + jx_p + a^2\bar{Z}_n)+\bar{Z}_F}$,

knowing that $\dfrac{xy}{x+y} = y - \dfrac{y^2}{x+y}$,

we have $\bar{Z}_W = \bar{Z}_F - \dfrac{(\bar{Z}_F)^2}{R_p + jx_p + a^2\bar{Z}_n + \bar{Z}_F}$

$$\bar{Z} = (\bar{Z}_{po} + \bar{Z}_F) - \frac{(\bar{Z}_F)^2}{R_p + jx_p + a^2\bar{Z}_n + \bar{Z}_F} \qquad [\Omega] \quad (1)$$

Knowing that $\bar{Z}_W = \bar{Z}_F - \dfrac{(\bar{Z}_F)^2}{R_p + jx_p + a^2\bar{Z}_n + \bar{Z}_F}$

Writing $\bar{Z}_{p0} = jL\omega$ we have $\bar{Z} = jL\omega + \bar{Z}_w$

We set $\alpha = \mathrm{Re}(\bar{Z}w)$ and $\beta = \mathrm{Im}(\bar{Z}w)$,

we have: $|Z| = Z = \sqrt{\alpha^2 + (L\omega + \beta)^2}$

IV. DIVISION RATIO (K) AND OUTPUT VOLTAGE V_2

V_2: Output voltage divider MV

V_Φ: single voltage transmission line on which the draw is made.

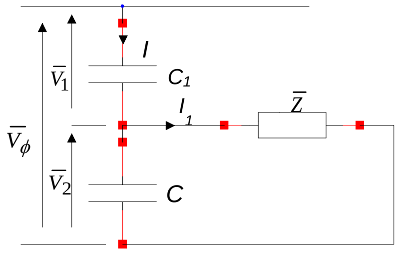

Fig.5: Simplified representation of the system

U is the voltage of the line was for phase-ground voltage $\bar{V}_\phi = \dfrac{U}{\sqrt{3}}$

$$\bar{Z}_1 = \frac{1}{jC_1\omega}; \quad \bar{Z}_2 = \frac{1}{jC_2\omega};$$

Ohm's law gives $\bar{V}_1 = \bar{Z}_1\bar{I}$ so and $\bar{V}_\phi = \bar{V}_1 + \bar{V}_2$ so $\bar{V}_2 = \bar{V}_\phi - \bar{V}_1 = \bar{V}_\phi - \bar{Z}_1\bar{I}$.

Call $\bar{Z}_{éq} = \bar{Z}_1 + \bar{Z}_2 // \bar{Z}$ that is to say

$$\bar{Z}_{éq} = \bar{Z}_1 + \frac{\bar{Z}_2\bar{Z}}{\bar{Z}_2 + \bar{Z}} \qquad [\Omega] \quad (2)$$

$\bar{Z}_{éq}$: Represents the equivalent impedance of the entire system connected to the line HV.

The main current is then $\bar{I} = \dfrac{\bar{V}_\phi}{\bar{Z}_{éq}}$

$$\bar{V}_2 = \bar{V}_\phi - \bar{Z}_1\left(\frac{\bar{V}_\phi}{\bar{Z}_{éq}}\right) = \bar{V}_\phi\left[1 - \frac{\bar{Z}_1}{\bar{Z}_{éq}}\right]$$

$$\bar{V}_2 = \bar{V}_\phi\left(1 - \frac{\bar{Z}_1}{\bar{Z}_1 + \dfrac{\bar{Z}_2\times\bar{Z}}{\bar{Z}_2 + \bar{Z}}}\right)$$

$$\bar{V}_2 = \bar{V}_\phi\left(\frac{1}{1 + \dfrac{\bar{Z}_1}{\bar{Z}_2} + \dfrac{\bar{Z}_1}{\bar{Z}}}\right) \qquad [V] \quad (3)$$

now $\bar{Z}_1 = \dfrac{1}{jC_1\omega}$; $\bar{Z}_2 = \dfrac{1}{jC_2\omega}$,

we find $\bar{V}_2 = \bar{V}_\phi\left(\dfrac{1}{1 + \dfrac{C_2}{C_1} + \dfrac{\bar{Z}_1}{\bar{Z}}}\right)$

$$\bar{V}_2 = \bar{V}_\phi\frac{C_1}{(C_1 + C_2)}\times\left[\frac{1}{1 + \dfrac{1}{j\omega(C_1 + C_2)\bar{Z}}}\right]$$

$$\boxed{\bar{V}_2 = \frac{\bar{V}_\phi}{\left(\dfrac{C_1 + C_2}{C_1}\right)}\left[\frac{1}{1 + \dfrac{1}{j\omega(C_1 + C_2)\bar{Z}}}\right]} \qquad (4)$$

transformation ratio $\bar{k} = \dfrac{\bar{V}_\phi}{\bar{V}_2}$

ratio is then: $\bar{k} = \dfrac{C_1 + C_2}{C_1} + \dfrac{1}{j\omega C_1\bar{Z}}$

$$\bar{k} = (\frac{C_1 + C_2}{C_1})\left[1 + \frac{1}{j\omega\bar{Z}(C_1 + C_2)}\right] \quad (5)$$

A schema opens $\bar{Z} = \infty$, so

$$\boxed{\bar{k} = k_0 = \frac{C_1 + C_2}{C_1}} \quad (6)$$

It has already been established that $\bar{Z}$ can be written $\bar{Z} = \alpha + j(L\omega + \beta)$. Transformation ratio.

$$\bar{k} = \frac{\bar{V}_\phi}{\bar{V}_2} = (\frac{C_1 + C_2}{C_1})\left[1 + \frac{1}{j\omega\bar{Z}(C_1 + C_2)}\right],$$

This indicates that the voltage $\bar{V}_2$ is in phase with the line voltage $\bar{V}_\phi$ of the power line that $\bar{k}$ is pure real.

So just what $\bar{Z} = \alpha + j(L\omega + \beta)$ is imaginary pure, and therefore

$$\boxed{\alpha = 0 \Rightarrow \bar{Z} = j(L\omega + \beta)} \quad [\Omega] \quad (7)$$

Of the formula of k, we understand that the voltage division ratio depends on $\bar{Z}$ and therefore much of the load $\bar{Z}_n$. The ratio k is not constant. The voltage regulation $\bar{V}_2$ is necessary because $\bar{V}_2$ varies with load $\bar{Z}_n$.

The relationship $k_0 = \frac{C_1 + C_2}{C_1}$ gives

$$\boxed{C_2 = (k_0 - 1)C_1} \quad [F] \quad (8)$$

It is known that k_0 is a constant strictly greater than 1.

The relationship $C_2 = (k_0 - 1)C_1$ shows that $C_2 > C_1$; the lowest capacity is one that is directly connected to the line.

a) The Study of impedance $\bar{Z}_{éq}$

The result $\bar{Z}_{éq} = \bar{Z}_1 + \frac{\bar{Z}_2 \times \bar{Z}}{\bar{Z}_2 + \bar{Z}}$,

$$\bar{Z}_{éq} = \frac{\bar{Z}_1\bar{Z}_2 + \bar{Z}_1\bar{Z} + \bar{Z}_2\bar{Z}}{\bar{Z}_2 + \bar{Z}}, \text{ so}$$

$$\frac{1}{\bar{Z}_{éq}} = \frac{jC_1 \times C_2\omega}{C_1 + C_2} \times \frac{(1 + \frac{1}{jC_2\omega\bar{Z}})}{(1 - \frac{j}{\omega\bar{Z}(C_1 + C_2)})}, \text{ So}$$

$$\boxed{\bar{Z}_{éq} = \frac{jC_1C_2\omega}{C_1 + C_2} \times \frac{(1 + \frac{1}{j\omega\bar{Z}(C_1 + C_2)})}{(1 + \frac{1}{jC_2\omega\bar{Z}})}} \quad [F] \quad (9)$$

As C_1 is small compared to C_2, to see what limit will tend $\bar{Z}_{éq}$ whatever $\bar{Z}$.

We have : $\frac{1}{C_1 + C_2} = \frac{1}{C_2}(\frac{1}{1 + \frac{C_1}{C_2}})$ with $\frac{C_1}{C_2} \to 0$

The limited development $\frac{1}{1 + x}$, with $|x| < 1$ being

$$\frac{1}{1 + x} = \sum_{k=0}^{n} (-1)^k x^k,$$

We can write :

$$\frac{1}{1 + (\frac{C_1}{C_2})} = \sum_{k=0}^{n} (-1)^k (\frac{C_1}{C_2})^k$$

and so $\frac{1}{C_1 + C_2} = \frac{1}{C_2}(\frac{1}{1 + \frac{C_1}{C_2}}) = \sum_{k=0}^{n} (-1)^k \frac{C_1{}^k}{C_2{}^{k+1}}$

$$= \frac{1}{C_2} + \sum_{k=1}^{n} (-1)^k \frac{C_1{}^k}{C_2{}^{k+1}}, \text{ so}$$

$$= \frac{C_1 + C_2}{jC_1C_2\omega} \times \left[1 + (\frac{1}{1 + jC_2\omega\bar{Z}}) \sum_{k=1}^{n} (-1)^k (\frac{C_1}{C_2})^k\right]$$

If we call the C_0 capacity equivalent to the set of two capacitors C_1 and C_2 supposed in series and $\bar{Z}_0$ the corresponding impedance, we would have:

$$\frac{1}{C_0} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{C_1 + C_2}{C_1 \times C_2}$$

from where $C_0 = \frac{C_1 \times C_2}{C_1 + C_2}$

$$\bar{Z}_0 = \frac{1}{j\omega C_0};$$

Development to order 2 gives:

$$\bar{Z}_{éq} = \bar{Z}_0\left[1 + \left(\frac{1}{1 + jC_2\omega\bar{Z}}\right)\left(\frac{-C_1}{C_2} + \left(\frac{C_1}{C_2}\right)^2\right)\right] \quad [\Omega] \quad (10)$$

Conclusion: As C_2 to C_1 is too large then so $\frac{C_1}{C_2} \to 0$

$$\bar{Z}_{éq} \to \bar{Z}_0$$

$$\boxed{\lim_{(\frac{C_1}{C_2}) \to 0} \bar{Z}_{éq} = \bar{Z}_0} \quad [\Omega] \quad (11)$$

In this case $\bar{Z}$ has no more influence and it is as if the system is idle. So if $C_2 >> C_1$ it $\bar{Z} = \infty$ is as if it is, as if the vacuum system.

$$\bar{Z}_{éq} \to \bar{Z}_0 = \frac{(C_1 + C_2)}{j\omega C_1 \times C_2}$$

b) Calculation of the current that passes through C_1

We already know that

$$\frac{1}{\bar{Z}_{éq}} = \frac{jC_1 \times C_2\omega}{C_1 + C_2} \times \frac{(1 + \frac{1}{jC_2\omega\bar{Z}})}{(1 - \frac{j}{\omega\bar{Z}(C_1 + C_2)})} \qquad \bar{I} = \frac{\bar{V}_\phi}{\bar{Z}_{éq}} \text{ gives}$$

with

$$\boxed{\bar{I} = \frac{jC_1C_2\omega V_\phi}{(C_1 + C_2)} \times \frac{(1 + \frac{1}{jC_2\omega\bar{Z}})}{(1 - \frac{j}{\omega\bar{Z}(C_1 + C_2)})}} \quad [A] \quad (12)$$

A empty (transformer MV/LV not connected) we have $\overline{Z} = \infty$

$$\boxed{I = I_0 = \frac{C_1 C_2 \omega V_\phi}{C_1 + C_2}} \quad [A] \qquad (13)$$

$$\overline{Z} = (\overline{Z}_{po} + \overline{Z}_F) - \frac{(\overline{Z}_F)^2}{R_p + jx_p + \overline{Z}_F + a^2 \frac{U_n^{\ 2}}{S_n} e^{j\varphi}}$$

This expression of the current (13) can also be written:

$$= (\frac{jC_1C_2\omega\overline{V}_\phi}{(C_1+C_2)}) \times (\frac{(1+\frac{1}{jC_2\omega\overline{Z}})}{(1+\frac{1}{j\omega\overline{Z}C_2(\frac{C_1}{C_2}+1)})}) \qquad (14)$$

C_1 little toward C_2 we have

$$\overline{I} \approx (\frac{jC_1C_2\omega\overline{V}_\phi}{(C_1+C_2)}) \times (\frac{(1+\frac{1}{jC_2\omega\overline{Z}})}{(1+\frac{1}{jC_2\omega\overline{Z}})})$$

$$\boxed{\overline{I} \approx \frac{jC_1C_2\omega\overline{V}_\phi}{C_1+C_2}} \quad [A] \qquad (15)$$

V. REACTIVE POWER

If $I_2 = |\overline{I}_2|$ and $I = |\overline{I}|$

Without the compensation coil, the power Q_c supplied by the capacitors is:

$$\boxed{Q_C = X_2(I_2)^2 + X_1(I)^2} \quad [VAR] \qquad (16)$$

Now $I_2 = \frac{V_2}{X_2}$ while $\overline{I}$ the expression of the main current has already been

calculated. $\overline{I} = (\frac{jC_1C_2\omega\overline{V}_\phi}{(C_1+C_2)}) \times (\frac{(1+\frac{1}{jC_2\omega\overline{Z}})}{(1+\frac{1}{j\omega\overline{Z}(C_1+C_2)})})$

we set $\overline{\delta} = \frac{1+\frac{1}{jC_2\omega\overline{Z}}}{1+\frac{1}{j\omega\overline{Z}(C_1+C_2)}}$

so

$$Q_C = X_2(\frac{V_2}{X_2})^2 + X_1(\frac{C_1C_2\omega}{C_1+C_2})^2|\overline{V}_\phi\overline{\delta}|^2 \quad [VAR] \qquad (17)$$

<u>Calculation:</u> $\overline{V}_\phi\overline{\delta}$: It had already been shown

$$\overline{V}_\phi = (\frac{C_1+C_2}{C_1})\left[1+\frac{1}{j\omega\overline{Z}(C_1+C_2)}\right]\overline{V}_2$$

The calculation $\overline{V}_\phi\overline{\delta}$ gives:

$$\boxed{\overline{V}_\phi\,\overline{\delta} = (\frac{C_1+C_2}{C_1})\left[1+\frac{1}{j\omega\overline{Z}C_2}\right]\overline{V}_2} \quad [V] \qquad (18)$$

Let us now expressed $\frac{1}{j\omega\overline{Z}C_2}$ as a function of the transformation ratio $k = \frac{\overline{V}_\phi}{\overline{V}_2}$.

But it had already been established previously that

$$k = (\frac{C_1+C_2}{C_1})\left[1+\frac{1}{j\omega\overline{Z}(C_1+C_2)}\right]$$

$$k = (\frac{C_1+C_2}{C_1})\left[1+\frac{1}{jC_2\omega\overline{Z}(1+\frac{C_1}{C_2})}\right];$$

which gives: $1+\frac{1}{jC_2\omega\overline{Z}(1+\frac{C_1}{C_2})} = \overline{k}\frac{C_1}{C_1+C_2}$,

or $\frac{1}{jC_2\omega\overline{Z}(1+\frac{C_1}{C_2})} = \overline{k}\frac{C_1}{C_1+C_2} - 1$ so

$$\frac{1}{jC_2\omega\overline{Z}} = (1+\frac{C_1}{C_2})\left[\overline{k}(\frac{C_1}{C_1+C_2})-1\right] \qquad (19)$$

So this expression reported in (19) gives:

$$\overline{V}_\phi\overline{\delta} = (\frac{C_1}{C_1+C_2})\overline{V}_2(1+(\frac{C_1+C_2}{C_2})(\frac{C_1\overline{k}}{(C_1+C_2)}-1))$$
$$= (\frac{C_1}{C_1+C_2})\overline{V}_2(1+\frac{C_1\overline{k}}{C_2}-\frac{(C_1+C_2)}{C_2})$$

$\overline{V}_\phi\overline{\delta} = (\frac{C_1+C_2}{C_2})\overline{V}_2(\overline{k}-1)$ so

$$\boxed{|\overline{V}_\phi\overline{\delta}| = (\frac{C_1+C_2}{C_2})V_2|(\overline{k}-1)|} \qquad (20)$$

and the expression

$Q_C = X_2(\frac{V_2}{X_2})^2 + X_1(\frac{C_1C_2\omega}{C_1+C_2})^2|\overline{V}_\phi\overline{\delta}|^2$ because :

$$Q_C = \frac{V_2^{\ 2}}{X_2} + X_1(\frac{C_1C_2\omega}{C_1+C_2})^2 \times (\frac{C_1+C_2}{C_2})^2 V_2^{\ 2}|\overline{k}-1|^2 \qquad (21)$$

$$Q_C = \frac{V_2^{\ 2}}{X_2} + X_1(C_1\omega)^2 V_2^{\ 2}|\overline{k}-1|^2$$

by replacing $X_1 = \frac{1}{C_1\omega}$ and $X_2 = \frac{1}{C_2\omega}$,

we find : $Q_C = C_2\omega V_2^{\ 2} + C_1\omega V_2^{\ 2}|\overline{k}-1|^2$;

$$\boxed{\frac{Q_C}{\omega(V_2)^2} = C_2 + C_1|\overline{k}-1|^2} \quad [F] \qquad (22)$$

V_2: MV voltage supplied to the MV / LV transformer and $\overline{k} = \frac{\overline{V}_\phi}{\overline{V}_2}$: complex transformation ratio

This result expresses the reactive power that would produce the capacitive divider from the capacities (C_1) and (C_2), $\overline{k}$ is

generally a complex number because there is no evidence that tensions $\overline{V}_\phi$ and $\overline{V}_2$ are in phase.

The value $\dfrac{Q_C}{\omega {V_2}^2}$ is within an interval of length L

C_1 value $\dfrac{Q_C}{\omega {V_2}^2}$ being low we see immediately that L

$$L = -\left[C_2 + C_1(\frac{V_\phi}{V_2} - 1)^2\right] + \left[C_2 + C_1(1 + \frac{V_\phi}{V_2})^2\right]$$

$$L = 2\frac{V_\phi}{V_2}C_1 + 2\frac{V_\phi}{V_2}C_1 = 4C_1\frac{V_\phi}{V_2} \qquad (23)$$

is as low as it can be considered as the value of $\dfrac{Q_C}{\omega {V_2}^2}$ the average of the two extreme values.

$$\frac{Q_C}{\omega {V_2}^2} \approx \frac{C_2 + C_1(\frac{V_\phi}{V_2} - 1)^2 + C_2 + C_1(\frac{V_\phi}{V_2} + 1)^2}{2}$$

$$\approx C_1 + C_2 + C_1(\frac{V_\phi}{V_2})^2$$

$$\boxed{\frac{Q_C}{\omega {V_2}^2} \approx C_1 + C_2 + C_1(\frac{V_\phi}{V_2})^2} \qquad [F] \qquad (24)$$

We can write that $Q_C \approx C_1\omega(V_\phi)^2 + (C_2 + C_1)\omega {V_2}^2$

$\overline{V}_\phi \sqrt{3}$ is the voltage of the line to HV it is imposed then that $\overline{V}_2$ will be the subject of a choice in relation to the capacity C_1 and C_2.

The expression Q_C imposes the choice of a low voltage $\overline{V}_2$ average risk of injecting too much reactive power in the network and therefore the over-sizing of the compensation coil.

VI. COIL COMPENSATION OF REACTIVE POWER INJECTED BY C_1 AND C_2

By adopting the solution of the total compensation, the coil of compensation must be able to absorb reactive power produced by the capacities C_1 and C_2.

This results in the following equation:

$$X_2{I_2}^2 + X_1 I^2 = X_L(I_1)^2 \qquad [VAR] \qquad (25)$$

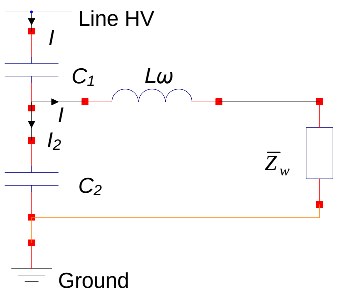

Fig.6: capacitive divider and Coil compensation

$$I_2 = \frac{V_2}{X_2} \qquad I_1 = \frac{V_2}{Z}$$

$$\bar{I} = \frac{jC_1C_2\omega V_\phi}{C_1 + C_2}) \times (1 + \frac{1 + \dfrac{1}{jC_2\omega\overline{Z}}}{1 + \dfrac{1}{jC_2\omega\overline{Z}(1 + \dfrac{C_1}{C_2})}}),$$

$$\bar{I} = \bar{I}_0 \times \bar{\delta}$$

Equation (30) becomes $\dfrac{{V_2}^2}{X_2} + X_1{I_0}^2\delta^2 = (L\omega)\dfrac{{V_2}^2}{Z^2}$

We had to establish that for a voltage $V_2 = \dfrac{C_1V_\phi}{C_1 + C_2}$, the power Q_C produced by the capacitors C_1 and C_2 takes its minimum value

$$Q_C = \frac{C_1C_2\omega {V_\phi}^2}{C_1 + C_2} \qquad (VAR)$$

The compensation coil here would be one that would swallow up the power Q_C

$$Q_C = Q_L, \quad \frac{C_1C_2\omega {V_\phi}^2}{C_1 + C_2} = (L\omega)\frac{{V_2}^2}{Z^2} \quad \text{now}$$

$$V_2 = \frac{C_1V_\phi}{C_1 + C_2} \text{ and } Z^2 = \alpha^2 + (L\omega + \beta)^2 \qquad (26)$$

$$\frac{C_1C_2\omega {V_\phi}^2}{C_1 + C_2} = (L\omega)\frac{(C_1V_\phi)^2}{(C_1 + C_2)^2\left[\alpha^2 + (L\omega + \beta)^2\right]}$$

$$C_2 = L\frac{C_1}{C_1 + C_2\left[\alpha^2 + (L\omega + \beta)^2\right]} \qquad (27)$$

$$C_2(C_1 + C_2)\left[\alpha^2 + (L\omega + \beta)^2\right] = LC_1$$

$$\alpha^2 + (L\omega + \beta)^2 = \frac{LC_1}{C_2(C_1 + C_2)} \qquad (28)$$

$$\boxed{(L\omega)^2 + (2\beta - \frac{C_1}{\omega C_2(C_1 + C_2)})(L\omega) + \alpha^2 + \beta^2 = 0} \qquad (29)$$

$$\alpha^2 + (L\omega)^2 + 2\beta(L\omega) + \beta^2 = \frac{\omega LC_1}{\omega C_2(C_1 + C_2)} \qquad (30)$$

Equation of second degree that $(L\omega)$ will determine the value of the compensation coil.

VII. STUDY OF THE VACUUM SYSTEM

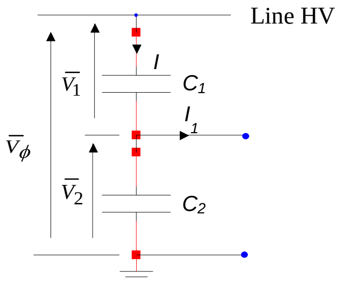

Fig.7: empty capacitive divider

In this case, assume that $\bar{Z} = \infty$ and therefore expression

$\bar{k} = (\frac{C_1 + C_2}{C_1})\left[1 + \frac{1}{j\omega\bar{Z}(C_1 + C_2)}\right]$ gives

$\bar{k} = (\frac{C_1 + C_2}{C_1})$, $\bar{k}$ becomes a pure real which implies that the voltages $\bar{V}_\phi$ and $\bar{V}_2$ are in phase; so

$$\bar{k} - 1 = 1 + \frac{C_2}{C_1} - 1 = \frac{C_2}{C_1} \quad (31)$$

so

$$\frac{Q_C}{\omega V_2^{\,2}} = C_2 + C_1\left|\bar{k} - 1\right|^2 = C_2 + C_1(\frac{C_2}{C_1})^2$$

$$Q_C = \omega C_2 V_2^{\,2}(1 + \frac{C_2}{C_1}) \quad (32)$$

$$Q_C = \omega(C_1 + C_2)\frac{C_2}{C_1}V_2^{\,2} \quad (33)$$

As $k - 1 = \frac{C_2}{C_1}$, we find

$$\boxed{Q_C = \omega(C_1 + C_2)(k - 1)V_2^{\,2}} \quad (34)$$

either

a) Va

$$\boxed{\frac{Q_C}{(V_2)^2} = \omega(C_1 + C_2)(k - 1)} \quad (35)$$

It was demonstrated that

$$\bar{V}_2 = \frac{\bar{V}_\phi}{(\frac{C_1 + C_2}{C_1})} \times \left[\frac{1}{1 + \frac{1}{j\omega(C_1 + C_2)\bar{Z}}}\right]$$

$\bar{V}_2$: MT output voltage divider

$\bar{V}_\phi = \frac{U}{\sqrt{3}}$: Line Voltage HT on which it is drawn off.

A vacuum $\bar{Z} = \infty$, was then $\bar{V}_{20} = \frac{\bar{V}_\phi}{(\frac{C_1 + C_2}{C_1})}$

$$\boxed{V_{20} = \frac{V_\phi}{(\frac{C_1 + C_2}{C_1})}} \quad [V] \quad (36)$$

b) Calculation of the current that passes through C_1 and C_2

We know that

$$I = \frac{jC_1C_2\omega V_\phi}{(C_1 + C_2)} \times \frac{(1 + \frac{1}{jC_2\omega\bar{Z}})}{(1 - \frac{j}{\omega\bar{Z}(C_1 + C_2)})}$$

A vacuum $\bar{Z} = \infty$ is found

$$I = I_0 = \frac{C_1C_2\omega V_\phi}{C_1 + C_2}$$

Another line of reasoning leads to the same result; indeed, to empty the capacity equivalent $C_{éq} = \frac{C_1 \times C_2}{C_1 + C_2}$ to the assembly of the two is at an impedance $Z_0 = \frac{1}{C_{éq}\omega} = \frac{C_1 + C_2}{\omega C_1 C_2}$,

The relationship $V_\phi = \frac{I_0}{C_{éq}\omega}$ led to $V_\phi = \frac{(C_1 + C_2)I_0}{\omega C_1 C_2}$

The same result is confirmed:

$$\boxed{I_0 = \frac{C_1C_2\omega V_\phi}{C_1 + C_2}} \quad (37)$$

VIII. APPLICATIONS IN CASE OF THE VILLAGE MOGROUM IN CHAD

On the assumption that one has a capacitive divider that provides a medium voltage of 20 kV from the potential line 220 kV project.

It was $V_\phi = \frac{220kV}{\sqrt{3}}$, we may exercise the load calculation to write

$$k_0 = \frac{C_1 + C_2}{C_1} = \frac{V_\phi}{U} = 6{,}35 \text{ and so } \frac{C_2}{C_1} = 5{,}35$$

Assuming a load current to the relatively low land of about 0.3 A, we write the equation:

$$I_0 = (\frac{C_1 \times C_2}{C_1 + C_2})\omega V_\phi \text{ with } \omega = 314 \text{ rad/s}$$

The combination of these two equations results in:

$$C_1 = 5{,}95nF \text{ and } C_2 = 31{,}80nF$$

A vacuum, such a divider would inject reactive power

$$Q_C = X_1(I_0)^2 + X_2(I_0)^2$$
$$= (X_1 + X_2)(I_0)^2$$

$$Q_C = (\frac{1}{C_1} + \frac{1}{C_2})\frac{I_0^{\,2}}{\omega} \quad [VAR] \quad (38)$$

Include: Q_C= 25 kVAR

IX. CONCLUSION

The system does not produce directly the low voltage, it requires the incorporation of an intermediate MV/LV transformer to supply the load LV. The maintenance of such system can be in favor of the rural populations of the developing countries.

REFERENCES

[1] BG CHECO – CEGELEC – Postes à couplage capacitif(SCC) pour électrification rurale fiable et rentable. Mars 1995

[2] A. OMBOUA - Thèse de doctorat 2002 - Université de liège : Alimentation de faibles charges directement des lignes à haute tension. PP 47-71.

[3] Iliceto F. ''lightly Loaded Long HV transmission Lines. Guidelines prepared at the request of the Word Bank'' Washington DC,1982-1983.

[4] Iliceto F, Cinieri E, Casely-Hayford L., Dokyi G. Operation results of an experimental system and Applications in Ghana, IEEE Transactions on Power Delivery, Vol.N°4, October 1989

[5] Cinieri E., Iliceto F., Dokyi G. Operation Results in Ghana''. African 1992, Swaziland, sept.1992, paper A-054.
[6] TURAN GÖNEN: Electric Power Transmission System Engineering: Analysis and Design. Copyrigt 1988 by John Willey
[7] Electrical Safety. A guide to the causes and prevention of electrical Hazards, J.Maxwell Adams. IEE power series 19, The Institution of Electrical Engineers, London, UK, 1994.
[8] Ch.S. Walker, ''Capacitance, Inductance and Cross-Talk Analysis'' Artech House, Boston, 1990.

Haroun Abba Labane,: Master's degree 2014 University of Brazzaville and PhD student in engineering sciences of the University of Brazzaville-Congo.

Pr. Alphonse Omboua is an electrical engineer; he received his PhD, from the University of Liege (Belgium) in 2002. He received a post-gradual diploma in Ouagadougou in rural development energies. He is presently lecturer at the University of Brazzaville-Congo, Dept. of electricity. He is expert of rural electrification (decentralized) using photovoltaic systems.